File Specification for GEOS-5 DAS Gridded Output

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To support NASA instrument teams with GEOS-5.x

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1. Introduction

This document describes the gridded output files from the version of the Goddard Earth Observing System Data Assimilation System (GEOS-5), which will support level-4 product generation. The intended audience is EOS instrument teams and other users of GEOS-5 products who need to write software to read GMAO products. The gridded data described in this document will be produced by the GEOS-5 Data Assimilation System (DAS) beginning in 2006 and be delivered to the Goddard Distributed Active Archive Center (DAAC), part of the EOSDIS Core System (ECS). The GMAO operational assimilation runs 4 times/day approximately 12 hours behind real-time. We will no longer produce First-look and Late-look versions of GMAO products. With the exception of reanalysis activities, there will be only one operational stream produced. Information on the status of GMAO product generation can be found at http://gmao.gsfc.nasa.gov/Operations/.

2. Format and File Organization

GEOS- 5 files are in HDF-EOS format, which is an extension of the Hierarchical Data Format (HDF), Version 4 developed at the National Center for Supercomputing Applications (NCSA). Each GEOS- 5 file will contain a single HDF-EOS grid, which in turn contains a number of geophysical quantities that we will refer to as "fields" or "variables." Some files will contain 2-D variables on a lon/lat grid and some files will contain 3-D variables on the same lon/lat grid but with an additional vertical dimension. In order to keep individual file sizes manageable, all files will contain only one valid data time, in contrast to the daily files produced by earlier GEOS systems.

The variables are created using the **GDdeffield** function from the HDF-EOS GD (grid) API which implements them as HDF Scientific Data Set (SDS) arrays so they can be read with standard HDF routines. In addition to the geophysical variables, the files will have SDS arrays that define dimension scales (or coordinate variables). There will be two distinct scales for each dimension, which will insure that a wide variety of graphical display tools can interpret the dimension scales. In particular, there is a set of dimension scales that adhere to the CF conventions as well as the older COARDS conventions (see References).

Due to the large size of these data files we will use szip, which provides a lossless compression of scientific data. Using szip, we can reduce our file sizes by 25 to 50% or even more. Szip has been integrated into HDF-4, release 2.0. The HDF-4 library must be compiled with the szip binary library and configured to use szip. Once the szip-enabled library is linked to an HDF-4 application, there should be no interface changes required to support reading szip'ed HDF. Details on downloading and building the HDF with szip support can be found at the NCSA HDF web site (see References).

ECS metadata and other information will be stored as global attributes. Note that metadata will change over the lifespan of the GEOS-5 system, so file sizes may not remain exactly the same over time.

2.1 Dimensions

GMAO HDF-EOS files will contain two sets of dimension scale (coordinate) information. One set of dimensions is defined using the **SDsetdimscale** function of the standard HDF SD interface. This set of scales will have an attribute named "units", set to an appropriate string defined by the CF and

COARDS conventions that can be used by applications to identify the dimension. The other set of dimension scales is created using the **GDdeffield/GDwritefield** functions as suggested in the ECS technical paper "Writing HDF-EOS Grid Products for Optimum Subsetting Services."

Table 2.1-1. Dimension Variables Contained in GMAO HDF-EOS Files

Name	Description	Type	*units* attribute
XDim:EOSGRID	longitude values	float32	degrees_east
YDim:EOSGRID	latitude values	float32	degrees_north
Height:EOSGRID (3D only)	pressure levels or lagrangian control volume (lcv) indices	float32	millibar or layer
TIME:EOSGRID	minutes since first time in file	float32	minutes since YYYY-MM-DD HH:MM:SS
XDim	longitude values	float64	N/A
YDim	latitude values	float64	N/A
Height (3D only)	pressure levels or lcv indices	float64	N/A
Time	seconds since 1/1/93	float64	N/A

The 32-bit dimension variables have a "units" attribute that makes them COARDS-compliant, while the 64-bit dimension variables satisfy ECS requirements.

2.2 Variables

Variables are stored as SDS arrays even though they are defined with the HDF-EOS **GDdeffield** function. As a result, one can use the SD interface of the HDF library to read any variable from the file. The only thing one must know is the short name of the variable and the dimensions. You can quickly list the variables in the file by using common utilities such as *ncdump* or *hdp* . Both utilities are distributed from NCSA with the HDF library. In Section 8 we will present sample code for reading one or more data fields from this file. The short names for all variables in all GMAO data products are listed in the File Collections section, Section 6.

Each variable will have metadata attributes defined that may be useful. Many of these attributes are required by the CF & COARDS conventions while others are for internal GMAO use. A listing of required attributes follows:

Table 2.2-1 Metadata attributes associated with each SDS.

Attribute Name	Attribute Type	Description
_FillValue	32-bit floating point	Floating-point value used to identify missing data. Will normally be set to 1e15. Required by CF.
missing_value	32-bit floating point	Same as _FillValue. Required for COARDS backwards compatibility.
valid_range	32-bit floating point array of	This attribute defines the valid range of the variable. The first element is the smallest valid

	size 2.	value and the second element is the largest valid value. Required by CF.
long_name	string	Ad hoc description of the variable. Required by COARDS.
standard_name	string	Standard description of the variable as defined in CF conventions. (See references)
units	string	The units of the variable. Must be a string that can be recognized by UNIDATA's Udunits package.
scale_factor	32-bit floating point	If variable is packed as 16-bit integers, this is the scale_factor for expanding to floating-point. Currently we do not plan to pack data, thus value will be 1.0
add_offset	32-bit floating point	If variable is packed as 16-bit integers, this is the offset for expanding to floating-point. Currently, we do no plan to pack data, thus value will be 0.0.

Other attributes may be present for internal GMAO use and can be ignored.

2.3 Global Attributes

In addition to SDS arrays containing variables and dimension scales, there is additional metadata stored in GMAO HDF-EOS files. Some of this metadata is required by the CF/COARDS conventions, some is present due to ECS requirements, and some may exist as a convenience to internal GMAO users. A summary of global attributes that will exist in all GMAO files is shown in Table 2.3-1.

Table 2.3-1 Metadata attributes associated with each SDS.

Attribute Name	Attribute Type	Description
Conventions	character	Identification of the file convention used, currently “CF-1.0”
title	character	Experiment identification, i.e. “Operational”
history	character	CVS tag used for this release. CVS tags are used internally by the GMAO to designate a particular version of the system.
institution	character	“NASA Global Modeling and Assimilation Office”
source	character	System Version
references	character	GMAO website address
comment	character	TBD

HDFEOSVersion	character	Version of the HDF-EOS library used to create this file.
StructMetadata.0	character	This is the GridStructure metadata that is created by the HDF-EOS library.
CoreMetadata.0	character	The ECS inventory metadata.
ArchivedMetadata.0	character	The ECS archive metadata.

3. Instantaneous vs Time-averaged Products

GEOS-5 gridded output files are identified as either instantaneous or time-averaged products. For upper-air fields, all pressure products are instantaneous and all lagrangian control volume (lcv) products are time-averaged. Single-level or surface products may be either instantaneous or time-averaged. The GMAO is no longer producing time-averaged pressure products, as was done with GEOS-3 and GEOS-4.

All instantaneous products contain fields that are snapshots of a specific time, with a single time per file. Upper-air products such as “inst3d_met_p" have a time frequency of 6 hours, with data valid at the four standard *synoptic times* (00 GMT, 06 GMT, 12 GMT, and 18 GMT). Instantaneous single-level products, such as “inst2d_met_x,” have a time-frequency of 3 hours, valid at the times listed above, plus the interim times of 03 GMT, 09 GMT, 15 GMT, and 21 GMT.

Time-averaged products are averaged over a 3-hour period for single-level files and over a 6-hour period for lcv files. Single-level products consist of 8 files per day, with time-stamps at the center of the 3-hour averaging interval (i.e., 01:30, 04:30, 07:30, 10:30, 13:30, 16:30, 19:30, and 22:30 GMT), and there is a single time period per file (e.g.,, the first file for a given day is time stamped with 01:30 GMT and represents the average between 00 GMT and 03 GMT). Time-averaged lcv-level products consist of 4 files/day, with time-stamps of 00, 06, 12, and 18 GMT, with each file time-stamped at the center of a 6-hour average (e.g., the first file of a given day is time-stamped with 00 GMT and represents an average between 21 GMT of the previous day and 03 GMT of the given day).

4. Grid Structure

GEOS-5 gridded output will be on a global 2/3 x 1/2 degree longitude-latitude horizontal grid, consisting of 540 points in the longitudinal direction and 361 points in the latitudinal direction. The horizontal grid origin is the lower-left point and represents the geolocation (-180.0 W, -90.0 S). Latitude or longitude as a function of the index can be determined by:

$$LON_I = -180 + (I-1) * dLON, \qquad I=1,540$$
$$LAT_J = -90 + (J-1) * dLAT, \qquad J=1,360$$

where dLON = 2/3° and dLAT = 1/2°. For all parameters of each file, a gridpoint represents the center of a box, i.e., the value at (LON=0,LAT=0) represents a box bounded by the points (LON=-0.33, LAT=0.25), (LON=-0.33,LAT=-0.25), (LON=0.33,LAT=-0.25), and (LON=0.33,LAT=0.25). Scalar values are the volume mean within the box.

The vertical structure of gridded products will have three different configurations: single-level (can be vertical averages or surface values), pressure-level, or lcv-level. Single-level data for a given variable appear as 3-dimensional fields (x,y,time) with multiple times spanning multiple files, while pressure-level data appear as 4-dimensional fields (x,y,z,time). Pressure-level data will be output on 36 pressure levels (hPa). The appropriate grid structure will be specified both in the filename and the metadata.

The GEOS-5 terrain-following lagrangian control volume (lcv) coordinates are similar to an eta coordinate system. There are 72 layers in the 5 lcv products: tavg3d_dyn_v, tavg3d_cld_v, tavg3d_mst_v, tavg3d_tmp_v, and tavg3d_wnd_v, with the values representing a layer-mean unless otherwise noted. Additionally there is the tavg3d_prs_v product, which contains the 72-layer variable "PL", which defines the layer-mean pressure at every horizontal grid-point. Note that the delta pressure for each layer ($DELP_{ijl}$) and the surface pressure (PS_{ij}) are also included in the tavg3d_prs_v product, allowing one to easily compute the pressure at the edges of each layer. In the GEOS-4 eta files, one could compute the pressure on the edges by using the “ak” and “bk” values and the surface pressure; once the edge pressures were known, they could be used to compute the average pressure in the layer. In GEOS-5, the full 3-dimensional pressure variables at are explicitly provided at both layer centers (PL_{ijl}) and layer edges (PLE_{ijl}). As of this writing the pressures reported are on a hybrid-sigma coordinate, and could be obtained from the “ak-bk” relationship. But this may change in the future and so users should rely on the reported 3-dimensional pressures and not attempt to compute them from “ak” and “bk”. Figure 1 is a schematic (not to scale) of the GEOS-5 LCV coordinate system. Note that the indexing in the vertical starts at the top, i.e., lcv layer 1 is the layer at the top of the atmosphere while lcv layer 72 is adjacent to the earth’s surface.

Variables that are only defined on layer edges (such as vertical fluxes between layers) are provided in the tavg3d_met_e product, which has 73 levels representing the top and bottom edges of the 72 lcv layers of the model. This product also contains the 3-D variable edge pressures "PLE".

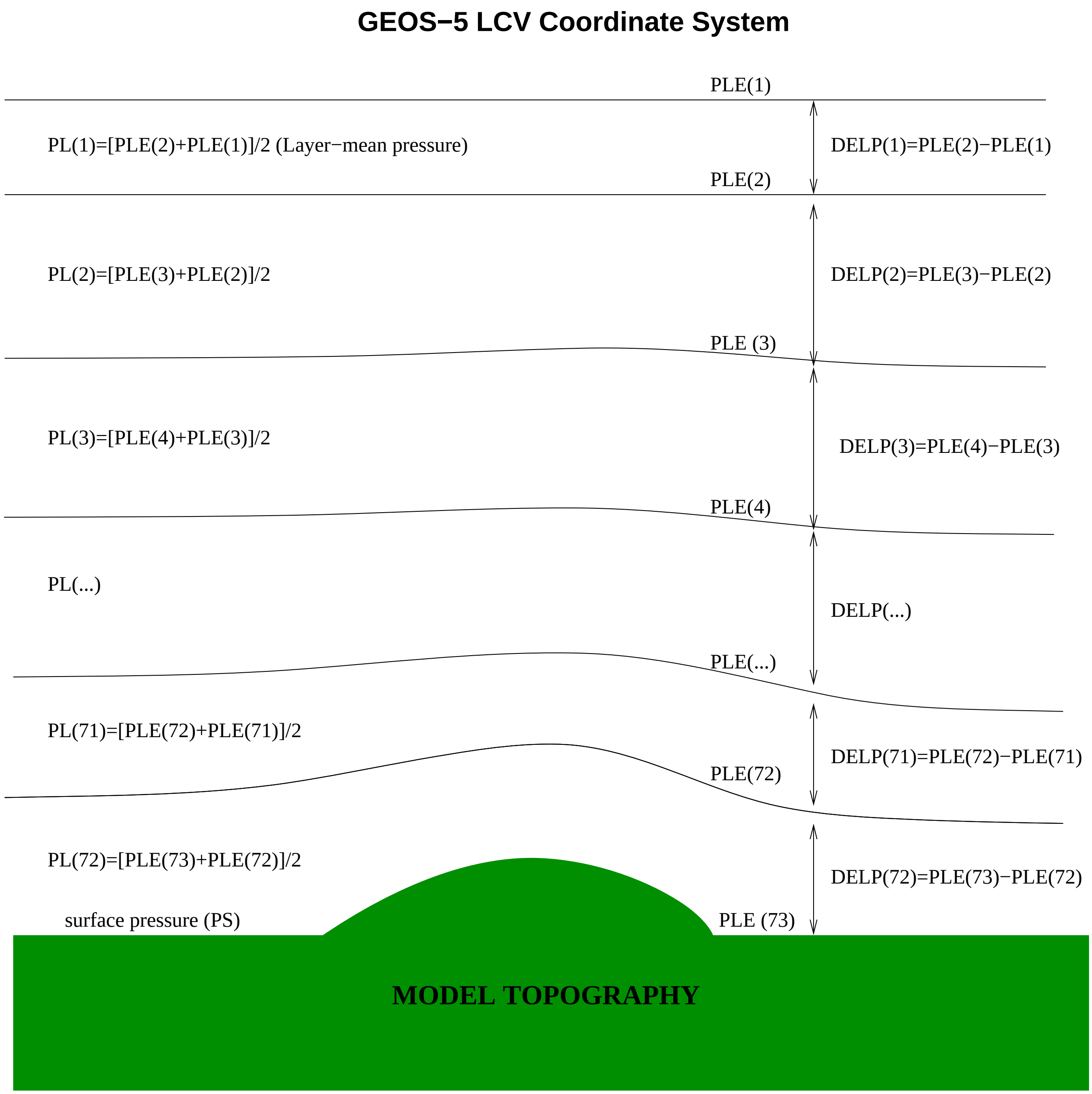

Figure 1: Schematic of GEOS-5 LCV coordinate system

5. File Naming Convention

Each GEOS-5 product will have a complete file name identified in the EOSDIS metadata as "LocalGranuleID". EOSDIS also requires abbreviated naming indices (8-character limit) for each Earth Science Data Type (ESDT). The ESDT indices convention is described in section 5.2.

5.1 File Name

The standard generic complete name for the assimilated GEOS- 5 configuration products will appear as follows:

DAS.config.mode.filetype.expid.yyyymmdd_hhmm.version

A brief description of the node fields appear below:

DAS:
Identifies output as a Data Assimilation System product.

config:
GEOS-5 will run in only one operational configuration. Other configurations may be added later.

ops - Operational assimilation, approximately 12 hours behind real-time.

mode:
GEOS-5 can run in different modes of operation, but the only mode used to support EOS instrument teams is "asm".

asm - Assimilation. Uses a combination of atmospheric data analysis and model forecasting to generate a time-series of global atmospheric quantities.

filetype:
The major filetypes are subdivided into file collections. Collections contain several fields with common characteristics. These collections are necessary to keep file sizes reasonable. Each filetype will contain the following information:

type/dimension_group_level

type/dimension:

There exist four possible type/dimension conventions for the DAS data products:

inst2d - 2-dimensional instantaneous fields (no time averaging).
inst3d - 3-dimensional instantaneous fields (no time averaging).
tavg2d - 2-dimensional 3-hour time averaged fields, time-stamped at the center of the averaging period. For example, 04:30z output would be a 3z-6z time average).
tavg3d - 3-dimensional 6-hour time averaged fields, time-stamped at the center of the averaging period. For example, 6z output would be a 3z-9z time average.

group:

met: meteorological fields
prs: pressure fields
dyn: dynamical fields
mst: moisture fields
tmp: temperature fields
wnd: wind fields

level: There are four possible level types for the DAS data:

x: single-level data (surface, column integrated, single-level)
p: pressure-level data (see Appendix C for pressure levels)
v: lagrangian control volume (lcv) layers
e: lagrangian control volume (lcv) layer edges

expid:
Experiment Identification. The GEOS-5 DAS data sets will be labeled:

GEOS5##

where ## is a two-digit number. The first operational release of GEOS-5 will have an experiment identification of GEOS501. When a modified version of GEOS-5 is used for either forward processing or reprocessing, we will increment the ## appropriately. As updated versions of the GEOS software are implemented in operations, the cvs tag in the metadata parameter "History" will be modified. Information on version upgrades will also be available on the GMAO operations status web page (http://gmao.gsfc.nasa.gov/operations/).

yyyymmdd_hhmm:
This node defines the date and time of the data in the file.

yyyy - year string (e.g. "2002")
mm - month string (e.g. "09" for September)
dd - day of the month string (e.g. "10" for the tenth day of the month)
hh – valid hour
mm – valid minutes (either “00” or “30”)

version:
This node defines the file version and takes the form V##. Under normal conditions ## will be 01. In the event of a processing error that requires a re-processing, this number will be incremented to identify the new version of this file. The file version will also be represented in the EOSDIS metadata as "LocalVersionID".

EXAMPLE:

DAS.ops.asm.tavg3d_dyn_v.GEOS501.20020915_0000.V01

This is an example of a DAS filename from the operational production. The data are 6-hour time averaged output on lcv levels (3 dimensions). The filetype consists of dynamical fields. The valid time for the data is Sep 15 at 00 GMT, which represents the 6-hour average from Sep 14 at 21 GMT through Sep 15 at 03 GMT. See the discussion on time-averaged data in section 3 for more information.

5.2 Earth Science Data Types (ESDT) Name

To accommodate EOSDIS toolkit requirements, GEOS-5 complete filenames are associated to shorter or abbreviated indices in the ESDTs. EOSDIS requires a short (8 character) name for each ESDT. Below is the abbreviated naming convention for the GEOS-5 gridded ESDTs. The standard ESDT naming convention for the GEOS-5 gridded output will have the form:

DSPTVCCC

D: DAS identifier. Always **D**.

S: Major system number. For GEOS-5, **5.**

P: Product

O = Operational

T: Type

I = Instantaneous
T = Time-averaged

V: Vertical Coordinate:

X = Single-Level
P = Pressure
V = lcv
E = lcv edge

CCC: Filetype

MET = meteorological
PRS = pressure
DYN = dynamics
MST = moisture
TMP = temperature
WND = wind

Example:

<u>Abbreviated Name</u>: D5OIPMET

<u>Complete Name</u>: DAS.ops.asm.inst3d_met_p.GEOS501.20020915_0000.V01

6. File Collections

Table 6-1. Summary of GEOS-5 data products.

Type	Description	ESDT	Frequency	Uncompressed size/day (Mb)	Compressed size/day (Mb)
inst2d_met_x	2D meteorological state, instantaneous at the surface, on a single-level, or vertically integrated	D5OIXMET	8/day	160	104
inst3d_met_p	3D meteorological state, instantaneous on pressure coordinates	D5OIPMET	4/day	1011	528
tavg2d_met_x	2D meteorological state, time-averaged at the surface, on a single-level, or vertically integrated	D5OTXMET	8/day	448	256
tavg3d_prs_v	3D pressure information, time-averaged on lcv coordinates	D5OTVPRS	4/day	452	104
tavg3d_dyn_v	3D dynamics fields, time-averaged on lcv coordinates	D5OTVDYN	4/day	2692	1748
tavg3d_cld_v	3D cloud & precipitation fields, time-averaged on lcv coordinates	D5OTVCLD	4/day	1796	320
tavg3d_met_e	3D meteorological fields, time-averaged on lcv coordinate layer edges	D5OTEMET	4/day	1368	684
tavg3d_mst_v	3D moisture tendency fields, time-averaged on lcv coordinates	D5OTVMST	4/day	1120	516
tavg3d_tmp_v	3D temperature tendency fields, time-averaged on lcv coordinates	D5OTVTMP	4/day	2021	1264
tavg3d_wnd_v	3D wind tendency fields, time-averaged on lcv coordinates	D5OTVWND	4/day	1797	1052
TOTAL			**48/day**	**12865**	**6576**

File Collections summary table.

6.1 Assimilated Instantaneous Files

Below are the variables that are output into each **inst** file. These are instantaneous fields (no time averaging). The approximate size of each file below is determined by the following:

A x B x C x D x E = bytes/file

where:

A: X-Dimension
B: Y-Dimension
C: Vertical dimension
D: Number of fields in file
E: Number of bytes per floating point number

The method for calculating sizes is the same in 6.1 and 6.2.

NOTE: All HDF variable names are UPPERCASE. Italicized sizes in ( )s are estimates of the compressed file size, which will vary from day to day.

- **inst2d_met_x** (1 time per file, 8 times per day: 00, 03, 06, 09, 12, 15, 18, 21)
  ECS short name: D5OIXMET
  ECS long name: DAS Operational 2d meteorological state, instantaneous
  Dimensions:
    longitude: 540
    latitude: 361
    vertical: 1
  Size: 540 x 361 x 1 x 26 x 4 = 20 *(13)* Mb
  Size/day: 160 *(104)* Mb

Variable Name	Description	Units
PHIS	Surface geopotential	$m^2\ s^{-2}$
PS	Surface pressure	Pa
DISPH	Displacement Height	m
EFLUX	Latent heat flux at surface	$W\ m^{-2}$
HFLUX	Sensible heat flux at surface	$W\ m^{-2}$
LWI	Surface types	0=water, 1=land, 2=ice
QV10M	Specific humidity at 10 m above displacement height	$kg\ kg^{-1}$
QV2M	Specific humidity at 2 m above displacement height	$kg\ kg^{-1}$
SLP	Sea level pressure	Pa
T10M	Temperature at 10 m above displacement height	K
T2M	Temperature at 2 m above displacement height	K
TAUX	Eastward (zonal) surface wind stress	$N\ m^{-2}$
TAUY	Northward (meridional) surface wind stress	$N\ m^{-2}$
TO3	Total Column Ozone	Dobson
TQI	Total Q ice (Ice water path)	$kg\ m^{-2}$
TQL	Total Q liquid (Liquid water path)	$kg\ m^{-2}$
TQV	Total Q vapor (Total precipitable water)	$kg\ m^{-2}$
TROPP	Tropopause pressure	Pa

Variable Name	Description	Units
TROPQ	Tropopause specific humidity	kg kg^{-1}
TROPT	Tropopause temperature	K
TSKIN	Skin temperature	K
TTO3	Tropospheric Total Column Ozone	Dobson
U10M	Eastward (zonal) wind at 10 m above displacement height	m s^{-1}
U2M	Eastward (zonal) wind at 2 m above displacement height	m s^{-1}
V10M	Northward (meridional) wind at 10 m above displacement height	m s^{-1}
V2M	Northward (meridional) wind at 2 m above displacement height	m s^{-1}

- **inst3d_met_p** (1 time per file, 4 files per day: 00, 06, 12, 18)

  ECS short name: D5OIPMET
  ECS long name: DAS Operational 3d meteorological state, instantaneous on pressure coordinates
  Dimensions:
  longitude: 540
  latitude: 361
  vertical pressure levels: 36
  Size: 540 x 361 x 36 x 9 x 4 = 253 *(132)* Mb
  Size/day: 1011 *(528)* Mb

Variable Name	Description	Units
H	Geopotential height	m
O3	Ozone Mixing Ratio	kg kg^{-1}
QI	Ice	kg kg^{-1}
QL	Liquid water	kg kg^{-1}
QV	Specific humidity	kg kg^{-1}
RH	Relative humidity	percent
T	Temperature	K
U	Zonal wind	m s^{-1}
V	Meridional wind	m s^{-1}

6.2 Model-generated Time Averaged Files

Below are the variables that are output in each "tavg" file. These are time-averaged fields. Single-level, or 2-dimensional data will be output every 3 hours while 3-dimensional data will be output every 6 hours.

- **tavg2d_met_x** (1 file per time, 8 files per day:01:30,04:30,07:30,10:30,13:30,16:30,19:30,22:30)
  ECS short name: D5OTXMET
  ECS long name: DAS Operational 2d meteorological fields, time-averaged
  Dimensions:
  longitude: 540
  latitude: 361
  vertical: 1
  Size: 540 x 361 x 1 x 72 x 4 = 56 *(32)* Mb
  Size/day: 448 *(256)* Mb

Variable Name	Description	Units
ALBEDO	Surface albedo	fraction
ALBNIRDF	Diffuse beam NIR surface albedo	fraction
ALBNIRDR	Direct beam NIR surface albedo	fraction
ALBVISDF	Diffuse beam VIS surface albedo	fraction
ALBVISDR	Direct beam VIS surface albedo	fraction
BSTAR	Surface buoyancy scale	m s^{-2}
CLDHGH	High-level (above 400 hPa) cloud fraction	fraction
CLDLOW	Low-level (1000-700 hPa) cloud fraction	fraction
CLDMID	Mid-level (700-400 hPa) cloud fraction	fraction
CLDTOT	Total cloud fraction	fraction
DISPH	Displacement Height	m
DTG	Total rate of change in skin temperature	K s^{-1}
EVAP	Evaporation from turbulence	kg m^{-2} s^{-1}
FRLAKE	Fraction of lake type in grid box	fraction
FRLAND	Fraction of land type in grid box	fraction
FRLANDICE	Fraction of land ice type in grid box	fraction
FROCEAN	Fraction of ocean in grid box	fraction
GRN	Vegetation greenness fraction	fraction
GWETROOT	Root zone soil wetness	fraction
GWETTOP	Top soil layer wetness	fraction
HFLUX	Sensible heat flux (positive upward)	W m^{-2}
LAI	Leaf area index	m^2 m^{-2}
LWGDWN	Surface downward longwave flux	W m^{-2}
LWGDWNCLR	Net surface downward longwave flux assuming clear sky	W m^{-2}
LWGNET	Net surface downward longwave flux at the ground	W m^{-2}
LWGUP	Longwave flux emitted from surface (upward)	W m^{-2}
LWI	Surface types	0=water, 1=land, 2=ice
LWTUP	Upward longwave flux at top of atmosphere	W m^{-2}
LWTUPCLR	Upward longwave flux at top of atmosphere assuming clear sky	W m^{-2}
PARDF	Surface downward photosynthetically active radiation diffuse flux	W m^{-2}

Variable Name	Description	Units
PARDR	Surface downward photosynthetically active radiation beam flux	W m^{-2}
PBLH	Planetary boundary layer height	m
PRECANV	Surface precipitation flux from anvils	kg m^{-2} s^{-1}
PRECCON	Surface precipitation flux from convection	kg m^{-2} s^{-1}
PRECLSC	Surface precipitation flux from large-scale	kg m^{-2} s^{-1}
PRECSNO	Surface snowfall flux	kg m^{-2} s^{-1}
PRECTOT	Total surface precipitation flux	kg m^{-2} s^{-1}
PS	Time averaged surface pressure	Pa
QV10M	Specific humidity interpolated to 10 m above the displacement height	kg kg^{-1}
QV2M	Specific humidity interpolated to 2 m above the displacement height	kg kg^{-1}
SLP	Sea level pressure	Pa
SNOMAS	Snow depth	kg m^{-2}
SWGDWN	Surface downward shortwave flux	W m^{-2}
SWGNET	Net surface downward shortwave flux	W m^{-2}
SWGNETCLR	Net surface downward shortwave flux assuming clear sky	W m^{-2}
SWTNET	Incident shortwave radiation at top of atmosphere	W m^{-2}
SWTUP	Top of atmosphere outgoing shortwave flux	W m^{-2}
SWTUPCLR	Top of atmosphere outgoing shortwave flux assuming clear sky	W m^{-2}
T10M	Temperature interpolated to 10 m above the displacement height	K
T2M	Temperature interpolated to 2 m above the displacement height	K
TAUGWX	Eastward (zonal) gravity wave surface stress	N m^{-2}
TAUGWY	Northward (meridional) gravity wave surface stress	N m^{-2}
TAUHGH	Optical thickness of high clouds	dimensionless
TAULOW	Optical thickness of low clouds	dimensionless
TAUMID	Optical thickness of mid-level clouds	dimensionless
TAUTOT	Optical thickness of all clouds	dimensionless
TAUX	Eastward (zonal) surface wind stress	N m^{-2}
TAUY	Northward (meridional) surface wind stress	N m^{-2}
TO3	Total Column Ozone	Dobson
TPW	Total precipitable water	kg m^{-2}
TROPP	Tropopause pressure	Pa
TROPQ	Tropopause specific humidity	kg kg^{-1}
TROPT	Tropopause temperature	K
TSKIN	Skin temperature	K
TTO3	Tropospheric Total Ozone Column	Dobson
U10M	Eastward (zonal) wind at 10 m above displacement height	m s^{-1}
U2M	Eastward (zonal) wind at 2 m above the displacement height	m s^{-1}
USTAR	Surface velocity scale	m s^{-1}

Variable Name	Description	Units
V10M	Northward (meridional) wind at 10 m above the displacement height	m s^{-1}
V2M	Northward (meridional) wind at 2 m above the displacement height	m s^{-1}
Z0H	Roughness length, sensible heat	m
Z0M	Roughness length, momentum	m

- **tavg3d_prs_v** (1 time per file, 4 files/day: 00, 06, 12, & 18)
  ECS short name: D5OTVPRS
  ECS long name: DAS Operational 3d pressure information, time-averaged on lcv coordinates
  Dimensions:
  longitude: 540
  latitude: 361
  vertical layers (lcv): 72
  Size: (540 x 361 x 72 x 2 x 4) + (540 x 361 x 1 x 1 x 4) = 113 *(26)* Mb
  Size/day: 452 *(104)* Mb

Variable Name	Description	Units
PS	Surface pressure (two-dimensional field)	Pa
DELP	Pressure difference between layer edges	Pa
PL	Layer pressure	Pa

- **tavg3d_dyn_v** (1 time per file, 4 files/day: 00, 06, 12, & 18)
  ECS short name: D5OTVDYN
  ECS long name: DAS Operational 3d dynamics fields, time-averaged on lcv coordinates
  Dimensions:
  longitude: 540
  latitude: 361
  vertical layers (lcv): 72
  Size: 540 x 361 x 72 x 12 x 4 = 673 *(437)* Mb
  Size/day: 2692 *(1748)* Mb

Variable Name	Description	Units
DTDTTOT	Temperature tendency from physics (total diabatic)	K s^{-1}
HGHT	Geopotential height at mid-layer	m
MFXC	Mass Flux (zonal direction) on the C-Grid	kg m-2 s-1
MFYC	Mass Flux (meridional direction) on the C-Grid	kg m-2 s-1
O3	Ozone Mixing Ratio	kg kg^{-1}
OMEGA	Vertical pressure velocity	Pa s^{-1}
PV	Ertel's potential vorticity	m^2 kg^{-1} sec^{-1}
QV	Specific humidity	kg kg^{-1}
RH	Relative humidity after cloud physics	percent
T	Temperature	K
U	U wind	m s^{-1}
V	V wind	m s^{-1}

- **tavg3d_cld_v** (1 time per file, 4 files/day: 00, 06, 12, & 18)
  ECS short name: D5OTVCLD

ECS long name: DAS Operational 3d cloud & precipitation fields, time-averaged, lcv coordinates
Dimensions:
longitude: 540
latitude: 361
vertical layers (lcv): 72
Size: 540 x 361 x 72 x 8 x 4 = 449 *(80)* Mb
Size/day: 1796 *(320)* Mb

Variable Name	Description	Units
CLOUD	3-D Cloud fraction	fraction
DQRCON	Rain production rate – convective	kg m^{-2} s^{-1}
DQRLSC	Rain production rate - large-scale	kg m^{-2} s^{-1}
DTRAIN	Detrainment cloud mass flux	kg m^{-2} s^{-1}
QI	Cloud ice water mixing ratio	kg kg^{-1}
QL	Cloud liquid water mixing ratio	kg kg^{-1}
TAUCLI	Cloud optical depth ice	dimensionless
TAUCLW	Cloud optical depth water	dimensionless

- **tavg3d_met_e** (1 time per file, 4 files/day: 00, 06, 12, & 18)

ECS short name: D5OTEMET
ECS long name: DAS Operational 3d meteorological fields, time-averaged on lcv layer edges
Dimensions:
longitude: 540
latitude: 361
vertical layer edges (lcv): 73
Size: 540 x 361 x 73 x 6 x 4 = 342 *(171)* Mb
Size/day: 1368 *(684)* Mb

Variable Name	Description	Units
PLE	Edge pressure	Pa
CMFMC	Total moist convection mass flux	kg m^{-2} s^{-1}
HGHTE	Geopotential height at layer edges	m
KH	Total scalar diffusivity	m^2 s^{-1}
KM	Total momentum diffusivity	m^2 s^{-1}
MFZ	Mass flux (vertical)	kg m-2 s-1

- **tavg3d_mst_v** (1 time per file, 4 files/day: 00, 06, 12, & 18)

ECS short name: D5OTVMST
ECS long name: DAS Operational 3d moist tendency fields, time-averaged on lcv coordinates
Dimensions:
longitude: 540
latitude: 361
vertical layers (lcv): 72
Size: 540 x 361 x 72 x 5 x 4 = 280 *(129)* Mb
Size/day: 1120 *(516)* Mb

Variable Name	Description	Units
DQIDTMST	Ice tendency from moist physics	kg kg^{-1} s^{-1}
DQLDTMST	Liquid water tendency from moist physics	kg kg^{-1} s^{-1}
DQVDTDYN	Water vapor tendency from dynamics	kg kg^{-1} s^{-1}

Variable Name	Description	Units
DQVDTMST	Water vapor tendency from moist physics	kg kg^{-1} s^{-1}
DQVDTTRB	Water vapor tendency from turbulence	kg kg^{-1} s^{-1}

- **tavg3d_tmp_v** (1 time per file, 4 files/day: 00, 06, 12, & 18)

  ECS short name: D5OTVTMP
  ECS long name: DAS Operational 3d temperature tendency fields, time-averaged, lcv coordinates
  Dimensions:
  longitude: 540
  latitude: 361
  vertical layers (lcv): 72
  Size: 540 x 361 x 72 x 9 x 4 = 505 *(316)* Mb
  Size/day: 2021 *(1264)* Mb

Variable Name	Description	Units
DTDTDYN	Temperature tendency from dynamics	K s^{-1}
DTDTFRI	Temperature tendency from frictional heating	K s^{-1}
DTDTGWD	Temperature tendency from gravity wave drag	K s^{-1}
DTDTLWR	Temperature tendency from long wave radiation	K s^{-1}
DTDTLWRCLR	Temperature tendency from long wave radiation (clear sky)	K s^{-1}
DTDTMST	Temperature tendency from moist physics	K s^{-1}
DTDTSWR	Temperature tendency from short wave radiation	K s^{-1}
DTDTSWRCLR	Temperature tendency from short wave radiation (clear sky)	K s^{-1}
DTDTTRB	Temperature tendency from turbulence	K s^{-1}

- **tavg3d_wnd_v** (1 time per file, 4 files/day: 00, 06, 12, & 18)

  ECS short name: D5OTVWND
  ECS long name: DAS Operational 3d wind tendency fields, time-averaged on lcv coordinates
  Dimensions:
  longitude: 540
  latitude: 361
  vertical layers (lcv): 72
  Size: 540 x 361 x 72 x 8 x 4 = 449 *(263)* Mb
  Size/day: 1797 *(1052)* Mb

Variable Name	Description	Units
DUDTDYN	U-wind tendency from dynamics	m s^{-2}
DUDTGWD	U-wind tendency from gravity wave drag	m s^{-2}
DUDTMST	U-wind tendency from moist physics	m s^{-2}
DUDTTRB	U-wind tendency from turbulence	m s^{-2}
DVDTDYN	V-wind tendency from dynamics	m s^{-2}
DVDTGWD	V-wind tendency from gravity wave drag	m s^{-2}
DVDTMST	V-wind tendency from moist physics	m s^{-2}
DVDTTRB	V-wind tendency from turbulence	m s^{-2}

7. Metadata

GEOS-5 gridded output files will include or be linked to two types of metadata. When using the HDF-EOS library and tools, the EOSDIS metadata will be used. Other utilities such as GrADS will use the CF metadata.

7.1 EOSDIS Metadata

The EOSDIS toolkit will only use the EOSDIS metadata. EOSDIS identifies two major types of metadata, collection and granule.

Collection metadata are stored in a separate index file. This file describes an ESDT and is like a card in a library catalog. Each GMAO data product will have an ESDT description in the EOS Core System that contains its unique collection attributes. Appendix B describes the ESDT collection metadata.

Granule metadata is the "table of contents" information stored on the data file itself. The EOSDIS granule metadata include:

- File name (local granule ID)
- Grid structure
- Number of times stored in the file (1)
- Number of vertical levels for each variable in this file
- Names of variables in this file
- Variable format (32-bit floating point, 16-bit integer, etc.)
- Variable storage dimensions

  2-d fields will have 3 storage dimensions, time, latitude and longitude

  3-d fields will have 4 storage dimensions, time, latitude, longitude and vertical levels
- "Missing" value for each variable
- Unpacking scale factor for each packed variable (see section 8)
- Unpacking offset value for each packed variable (see section 8)

7.2 CF Metadata

When GrADS or FERRET are used to view GEOS-5 gridded data sets, the application will use the CF metadata imbedded in the data products. These metadata will comply with the CF conventions and include the following information:

- Space-time grid information (dimension variables)
- Variable long names (descriptions)
- Variable units
- "Missing" value for each variable

- Unpacking scale factor for each packed variable (see section 8)
- Unpacking offset value for each packed variable (see section 8)

8. Sample Software

Presented here is software that illustrates using the standard HDF library or the ECS HDF-EOS library to read GEOS-5 products. The program shown below will accept as command line arguments a file name and a field name. It will open the file, read the requested field at the first time, compute an average for this field, and print the result to standard output. There are two versions of this program. The first version uses the HDF-EOS library to read the file. The second version uses the standard HDF library to read the file. Electronic copies of these programs can be obtained from the Operations section of the GMAO web page:

http://GMAO.gsfc.nasa.gov/Operations/

```
/*****************************************************************************/
/* This program demonstrates how to read a field from a GMAO HDF-EOS */
/* product using the HDF-EOS library. It will take a file name and */
/* field name on the command line, read the first time of the given */
/* field, calculate an average of that time and print the average. */
/* */
/* usage: avg <file name> <field name> */
/* */
/* Rob Lucchesi */
/* rlucchesi@GMAO.gsfc.nasa.gov */
/* 2/12/1999 */
/*****************************************************************************/

#include "hdf.h"
#include "mfhdf.h"
#include <stdio.h>

#define XDIM 540
#define YDIM 361
#define ZDIM 36

main(int argc,char *argv[]) {
int32 sd_id, sds_id, status;
int32 sds_index;
int32 start[4], edges[4], stride[4];
char *fname, *vname;
float32 data_array[ZDIM][YDIM][XDIM];
float32 avg, sum;
int32 i,j,k;
int32 file_id, gd_id;

if (argc != 3) {
printf("Usage: avg <filename> <field> \n");
exit (-1);
}

fname = argv[1];
```

```
vname = argv[2];

/* Open the file (read-only) */

file_id = GDopen (fname, DFACC_RDONLY);
if (file_id < 0) {
printf ("Could not open %s\n",fname);
exit(-1);
}

/* Attach to the EOS grid contained within the file. */
/* The GMAO uses the generic name "EOSGRID" for the grid in all products. */

gd_id = GDattach (file_id,"EOSGRID");
if (gd_id < 0) {
printf ("Could not open %s\n",fname);
exit(-1);
}

/* Set positioning arrays to read the entire field at the first time. */

start[0] = 0;
start[1] = 0;
start[2] = 0;
start[3] = 0;

stride[0] = 1;
stride[1] = 1;
stride[2] = 1;
stride[3] = 1;

edges[0] = 1;
edges[1] = ZDIM;
edges[2] = YDIM;
edges[3] = XDIM;

/*
```

In this program, we read the entire field. By manipulating the start and edges arrays, it is possible to read a subset of the entire array. For example, to read a 3D section defined by x=100,224; y=50,149; z=15,16 you would set the start and edges arrays to the following:

```
start[0] = 0; time start location
start[1] = 15; z-dim start location
start[2] = 50; y-dim start location
start[3] = 100; x-dim start location

edges[0] = 1; time length
edges[1] = 2; z-dim length
edges[2] = 100; y-dim length
edges[3] = 125; x-dim length

*/

/* Read the data into data_array */

status = GDreadfield (gd_id, vname, start, stride, edges, data_array);
printf ("Read status=%d\n",status);

/* Calculate and print the average */

sum=0.0;
for (i=0; i<XDIM; i++)
for (j=0; j<YDIM; j++)
for (k=0; k<ZDIM; k++)
sum += data_array[k][j][i];

avg = sum/(XDIM*YDIM*ZDIM);

printf ("Average of %s in 3 dimensions is=%f\n",vname,avg);

/* Close file. */

status = GDdetach (gd_id);
status = GDclose (file_id);

}
```

```
/*************************************************************************/
/* This program demonstrates how to read a field from a GMAO HDF-EOS */
/* product using the HDF library (HDF-EOS not required). It will take */
/* a file name and field name on the command line, read the first time */
/* of the given field, calculate an average of that time and print the average. */
/* */
/* usage: avg <file name> <field name> */
/* */
/* Rob Lucchesi */
/* rlucchesi@GMAO.gsfc.nasa.gov */
/* 2/12/1999 */
/*************************************************************************/

#include "hdf.h"
#include "mfhdf.h"
#include <stdio.h>

#define XDIM 540
#define YDIM 361
#define ZDIM 36

main(int argc,char *argv[]) {
int32 sd_id, sds_id, status;
int32 sds_index;
int32 start[4], edges[4], stride[4];
char *fname, *vname;
float32 data_array[ZDIM][YDIM][XDIM];
float32 avg, sum;
int32 i,j,k;

if (argc != 3) {
printf("Usage: avg <filename> <field> \n");
exit (-1);
}

fname = argv[1];
vname = argv[2];

/* Open the file (read-only) */

sd_id = SDstart (fname, DFACC_RDONLY);
if (sd_id < 0) {
printf ("Could not open %s\n",fname);
exit(-1);
}

/* Find the index and ID of the SDS for the given variable name. */

sds_index = SDnametoindex (sd_id, vname);
```

```
if (sds_index < 0) {
printf ("Could not find %s\n",vname);
exit(-1);
}

sds_id = SDselect (sd_id,sds_index);

/* Set positioning arrays to read the entire field at the first time. */

start[0] = 0;
start[1] = 0;
start[2] = 0;
start[3] = 0;

stride[0] = 1;
stride[1] = 1;
stride[2] = 1;
stride[3] = 1;

edges[0] = 1;
edges[1] = ZDIM;
edges[2] = YDIM;
edges[3] = XDIM;

/*
In this program, we read the entire field. By manipulating the start
and edges arrays, it is possible to read a subset of the entire array.
For example, to read a 3D section defined by x=100,224; y=50,149;
z=15,16 you would set the start and edges arrays to the following:

start[0] = 0; time start location
start[1] = 15; z-dim start location
start[2] = 50; y-dim start location
start[3] = 100; x-dim start location

edges[0] = 1; time length
edges[1] = 2; z-dim length
edges[2] = 100; y-dim length
edges[3] = 125; x-dim length

*/

/* Read the data into data_array */

status = SDreaddata (sds_id, start, stride, edges, (VOIDP) data_array);
printf ("read status=%d\n",status);

/* Calculate and print the average */
```

```
sum=0.0;
for (i=0; i<XDIM; i++)
for (j=0; j<YDIM; j++)
for (k=0; k<ZDIM; k++)
sum += data_array[k][j][i];

avg = sum/(XDIM*YDIM*ZDIM);


printf ("Average of %s in 3 dimensions is=%f\n",vname,avg);

/* Close file. */

status = SDendaccess (sds_id);
status = SDend (sd_id);

}
```

Appendix A. Types of Assimilation Configurations

Operational Assimilation. Atmospheric observations from satellites, balloons, aircraft, ships, and other sources are grouped into six-hour data windows and processed by the atmospheric analysis four times each day. The operational analysis will run approximately 12 hours after the 4 analysis times (0Z, 6Z, 12Z, 18Z). It will run using whatever conventional and satellite observations are available at the data cut-off time. Products produced from this and any other *assimilation* are a combination of output from the statistical analysis system and a short GCM forecast.

Forecast/Simulation. This is a GCM forecast, with no insertion of atmospheric data via the analysis. The only outside data that enters the system are the boundary conditions, i.e., sea surface temperature and sea-ice concentration. Five-day forecasts are typically generated to support NASA field campaigns and to assess assimilation and forecast skill. Multi-year simulations are produced to investigate the climatology of the GCM. GMAO forecast products are not distributed to ECS and file formats are not discussed in this document.

Reprocessing. The GMAO may reprocess specified time periods since EOS-Terra launch using a recent version of the GEOS DAS software to support instrument team reprocessing requirements. It is expected that new ECS ESDTs will be generated for each reprocessing run.

Reanalysis. The GMAO will occasionally run reanalysis experiments. Reanalysis is the same as reprocessing except the time period is often much longer and not necessarily part of the EOS period. Reanalysis experiments are often run using baseline versions of the GEOS DAS system to support a wide variety of research activities internal and external to the GMAO. Unique ESDTs will be generated for any reanalysis data distributed through ECS.

Appendix B. Collection Metadata

GEOS-5 collection metadata will contain the following. To view the ESDTs associated with GMAO products, which include collection metadata, see the GMAO Operations web page: http://gmao.gsfc.nasa.gov/operations.

ECS Collection
- Revision Date
- Suggested Usage

Single Type Collection
- Collection State
- Maintenance and Update Frequency

Spatial
- Spatial Coverage Type

Bounding Rectangle
- West Bounding Coordinate
- North Bounding Coordinate
- East Bounding Coordinate
- South Bounding Coordinate

Altitude System Definition (for 3d files only)
- Altitude Datum Name
- Altitude Distance Units
- Altitude Encoding Method
- Altitude Resolution Class
- Altitude Resolution

Depth System Definition (land surface files only)
- Depth Datum Name
- Depth Distance Units
- Depth Encoding Method
- Depth Resolution Class
- Depth Resolution

Geographic Coordinate System
- Latitude Resolution
- Longitude Resolution
- Geographic Coordinate Units

Temporal
- Time Type
- Date Type
- Temporal Range Type
- Precision of Seconds
- Ends at Present Flag

Range Date Time

Range Beginning Date
Range Beginning Time
Range Ending Date
Range Ending Time

Contact Person

Role
Hours of Service
Contact Job Position
Contact First Name
Contact Middle Name
Contact Last Name

Contact Person Address

Street address
City
State/Province
Postal Code
Country

Telephone

Telephone Container
Telephone Number
Telephone Number Type

Email

Electronic Mail Address

Contact Organization

Role
Hours of Service
Contact Instruction
Contact Organization Name

Contact Organization Address

Street Address
City
State/Province
Postal Code
Country

Organization Telephone Number

Telephone Number
Telephone Number Type

Organizational Email

Electronic Mail Address

Discipline Topic Parameters

ECS Discipline Keyword
ECS Topic Keyword
ECS Term Keyword
ECS Variable Keyword
ECS Parameter Keyword

Temporal Keyword Class

Temporal Keyword

Spatial Keyword Class

Spatial Keyword

Processing Level

Processing Level Description
Processing Level ID

Analysis Source

Analysis Short Name
Analysis Long Name
Analysis Technique
Analysis Type

CSDT Description

Primary CSDT

Additional Attributes

Additional Attribute Data Type
Additional Attribute Description
Additional Attribute Name

Physical Parameter Details

Parameter Units of Measure
Parameter Range
Parameter Value Accuracy
Parameter Value Accuracy Explanation
Parameter Measurement Resolution

Storage Medium Class (filled in by DAAC)

Storage Medium

Appendix C. Vertical Grid Structure

Pressure-level data will be output on the following 36 pressure levels:

Level	Pressure (hPa)	Level	Pressure (hPa)	Level	Pressure (hPa)
1	1000	13	600	25	50
2	975	14	550	26	40
3	950	15	500	27	30
4	925	16	450	28	20
5	900	17	400	29	10
6	875	18	350	30	7
7	850	19	300	31	5
8	825	20	250	32	3
9	800	21	200	33	2
10	750	22	150	34	1
11	700	23	100	35	0.4
12	650	24	70	36	0.2

Appendix D: Table mapping variable names from GEOS-3, GEOS-4, and GEOS-5

Table of variable names (2D instantaneous)

GEOS-3 name product: tsyn2d_mis_x	GEOS-4 name product: tsyn2d_mis_x	GEOS-5 name product:inst2d_met_x
PHIS ($m^2 s^{-2}$)	PHIS ($m^2 s^{-2}$)	PHIS ($m^2 s^{-2}$)
ALBEDO (fraction)		
PS (hPa)	PS (hPa)	PS (Pa)
SLP (hPa)	SLP (hPa)	SLP (Pa)
		DISPH (m)
SURFTYPE (index)	SURFTYPE (0=water,1=land,2=ice)	LWI (0=water,1=land,2=ice)
VAVEU ($m s^{-1}$)		
VAVEV ($m s^{-1}$)		
VAVET(K)		
TPW ($g cm^{-2}$)		
GWET (fraction)		
SNOW (mm)		
TGROUND (K)	TSKIN (K)	TSKIN (K)
T2M (K)	T2M (K)	T2M (K)
T10M (K)	T10M (K)	T10M (K)
Q2M ($g kg^{-1}$)	Q2M ($g kg^{-1}$)	QV2M ($kg kg^{-1}$)
Q10M ($g kg^{-1}$)	Q10M ($g kg^{-1}$)	QV10M ($kg kg^{-1}$)
U2M ($m s^{-1}$)	U2M ($m s^{-1}$)	U2M ($m s^{-1}$)
U10M ($m s^{-1}$)	U10M ($m s^{-1}$)	U10M ($m s^{-1}$)
V2M ($m s^{-1}$)	V2M ($m s^{-1}$)	V2M ($m s^{-1}$)
V10M ($m s^{-1}$)	V10M ($m s^{-1}$)	V10M ($m s^{-1}$)
TROPP (hPa)	TROPP (hPa)	TROPP (Pa)
TROPT (K)	TROPT (K)	TROPT (K)
	TROPQ ($g kg^{-1}$)	TROPQ ($kg kg^{-1}$)
	UFLUX ($N m^{-2}$)	UFLUX ($N m^{-2}$)
	VFLUX ($N m^{-2}$)	VFLUX ($N m^{-2}$)
	HFLUX ($W m^{-2}$)	HFLUX ($W m^{-2}$)
		EFLUX ($W m^{-2}$)
		TQV ($kg m^{-2}$)
		TQL ($kg m^{-2}$)
		TQI ($kg m^{-2}$)
		TO3 (Dobson)
		TTO3 (dobson)

Table of variable names (3D instantaneous)

GEOS-3 name product: tsyn3d_mis_p	GEOS-4 name product: tsyn3d_mis_p	GEOS-5 name product:inst3d_met_p
UWND ($m s^{-1}$)	UWND ($m s^{-1}$)	U ($m s^{-1}$)
VWND ($m s^{-1}$)	VWND ($m s^{-1}$)	V ($m s^{-1}$)
HGHT (m)	HGHT (m)	H (m)
TMPU (K)	TMPU (K)	T (K)
SPHU ($g kg^{-1}$)	SPHU ($g kg^{-1}$)	QV ($kg kg^{-1}$)
		QL ($kg kg^{-1}$)
		QI ($kg kg^{-1}$)
		O3 ($kg kg^{-1}$)
RH (percent)	RH (percent)	RH (percent)
OMEGA ($hPa day^{-1}$)		

Table of variable names (2D time-averaged)

GEOS-3 name product: various	GEOS-4 name product: various	GEOS-5 name product: tavg2d_met_x
		FRLAKE (fraction)
		FRLAND (fraction)
		FRLANDICE (fraction)
		FROCEAN (fraction)
PREACC (mm day^{-1})	PREACC (mm day^{-1})	PRECTOT (kg m^{-2} s^{-1})
PRECON (mm day^{-1})	PRECON (mm day^{-1})	PRECCON (kg m^{-2} s^{-1})
	PRECL (mm day^{-1})	PRECLSC (kg m^{-2} s^{-1})
		PRECANV (kg m^{-2} s^{-1})
		PRECSNO (kg m^{-2} s^{-1})
TPW (g cm^{-2})	TPW (g cm^{-2})	TPW (kg m^{-2})
EVAP (mm day^{-1})	EVAP (mm day^{-1})	EVAP (kg m^{-2} s^{-1})
HFLUX (W m^{-2})	HFLUX (W m^{-2})	HFLUX (W m^{-2})
	GWETROOT (fraction)	GWETROOT (fraction)
	GWETTOP (fraction)	GWETTOP (fraction)
QICE (W m^{-2})		
CT (m s^{-1})		
TGROUND (K)	TSKIN (K)	TSKIN (K)
T2M (K)	T2M (K)	T2M (K)
T10M (K)	T10M (K)	T10M (K)
Q2M (g kg^{-1})	Q2M (g kg^{-1})	QV2M (kg kg^{-1})
Q10M (g kg^{-1})	Q10M (g kg^{-1})	QV10M (kg kg^{-1})
RADLWG (W m^{-2})	RADLWG (W m^{-2})	LWGNET (W m^{-2})
RADSWG (W m^{-2})	RADSWG (W m^{-2})	SWGNET (W m^{-2})
		SWGDWN (W m^{-2})
ALBEDO (fraction)	ALBEDO (fraction)	ALBEDO (fraction)
ALBVISDR (fraction)	ALBVISDR (fraction)	ALBVISDR (fraction)
ALBVISDF (fraction)	ALBVISDF (fraction)	ALBVISDF (fraction)
ALBNIRDR (fraction)	ALBNIRDR (fraction)	ALBNIRDR (fraction)
ALBNIRDF (fraction)	ALBNIRDF (fraction)	ALBNIRDF (fraction)
LWGCLR (W m^{-2})	LWGCLR (W m^{-2})	LWGDWNCLR (W m^{-2})
SWGCLR (W m^{-2})	SWGCLR (W m^{-2})	SWGNETCLR (W m^{-2})
VAVEUQ (m g s^{-1} kg^{-1})	VAVEUQ (m g s^{-1} kg^{-1})	
VAVEVQ (m g s^{-1} kg^{-1})	VAVEVQ (m g s^{-1} kg^{-1})	
VAVEUT (m K s^{-1})	VAVEUT (m K s^{-1})	
VAVEVT (m K s^{-1})	VAVEVT (m K s^{-1})	
	VAVEU (m s^{-1})	
	VAVEV (m s^{-1})	
	VAVET (K)	
VAVEQIAU (mm day^{-1})		
VAVEQFIL (mm day^{-1})		
VAVETIAU (K day^{-1})		
RAINCON (mm day^{-1})	RAINCON (mm day^{-1})	PRECCON (kg m^{-2} s^{-1})
SNOWFALL (mm day^{-1})		PRECSNO (kg m^{-2} s^{-1})
RAINLSP (mm day^{-1})	RAINLSP (mm day^{-1})	PRECLSC (kg m^{-2} s^{-1})
LWGDOWN (W m^{-2})	LWGDOWN (W m^{-2})	LWGDWN (W m^{-2})
LWGUP (W m^{-2})	LWGUP (W m^{-2})	LWGUP (W m^{-2})
PARDF (W m^{-2})	PARDF (W m^{-2})	PARDF (W m^{-2})
PARDR (W m^{-2})	PARDR (W m^{-2})	PARDR (W m^{-2})
LAI (index)	LAI (index)	LAI (m m^{-2})

GEOS-3 name product: various	GEOS-4 name product: various	GEOS-5 name product: tavg2d_met_x
GREEN (percent)		GRN (fraction)
DLWDTC (W m^{-2} K^{-1})		
DTG (K s^{-1})	DTG (K s^{-1})	DTG (K s^{-1})
SNOW (mm)	SNOW (mm)	SNOMAS (kg m^{-2})
PS (hPa)	PS (hPa)	PS (Pa)
UFLUX (N m^{-2})	UFLUX (N m^{-2})	TAUX (N m^{-2})
VFLUX (N m^{-2})	VFLUX (N m^{-2})	TAUY (N m^{-2})
GWDUS (N m^{-2})	GWDUS (N m^{-2})	TAUGWX (N m^{-2})
GWDVS (N m^{-2})	GWDVS (N m^{-2})	TAUGWY (N m^{-2})
GWDUT (N m^{-2})		
GWDVT (N m^{-2})		
CU		
USTAR (m s^{-1})	USTAR (m s^{-1})	USTAR (m s^{-1})
		BSTAR (m s^{-1})
Z0 (m)		
	Z0H (m)	Z0H (m)
	Z0M (m)	Z0M (m)
		DISPH (m)
PBL (hPa)	PBLH (m)	PBLH (m)
U2M (m s^{-1})	U2M (m s^{-1})	U2M (m s^{-1})
V2M (m s^{-1})	V2M (m s^{-1})	V2M (m s^{-1})
U10M (m s^{-1})	U10M (m s^{-1})	U10M (m s^{-1})
V10M (m s^{-1})	V10M (m s^{-1})	V10M (m s^{-1})
PIAU (hPa day^{-1})		
OLR (W m^{-2})	OLR (W m^{-2})	LWTUP (W m^{-2})
OLRCLR (W m^{-2})	OLRCLR (W m^{-2})	LWTUPCLR (W m^{-2})
RADSWT (W m^{-2})	RADSWT (W m^{-2})	SWTNET (W m^{-2})
OSR (W m^{-2})	OSR (W m^{-2})	SWTUP (W m^{-2})
OSRCLR (W m^{-2})	OSRCLR (W m^{-2})	SWTUPCLR (W m^{-2})
CLDFRC (fraction)	CLDFRC (fraction)	CLDTOT (fraction)
TAULOW (dimensionless)		TAULOW (dimensionless)
TAUMID (dimensionless)		TAUMID (dimensionless)
TAUHI (dimensionless)		TAUHGH (dimensionless)
		TAUTOT (dimensionless)
CLDLOW (fraction)	CLDLOW (fraction)	CLDLOW (fraction)
CLDMID (fraction)	CLDMID (fraction)	CLDMID (fraction)
CLDHI (fraction)	CLDHI (fraction)	CLDHGH (fraction)
CLDTMP (K)		
CLDPRS (hPa)		
		LWI (0=water,1=land,2=ice)

Table of variable names (3D time-averaged)

GEOS-3 name product: various on pressure	GEOS-4 name product: various on pressure & eta	GEOS-5 name product: various on lcv coordinates
TAUCLD (dimensionless)		
	TAUCLI (dimensionless)	TAUCLI (dimensionless)
	TAUCLW (dimensionless)	TAUCLW (dimensionless)
CLDTOT (fraction)	CLDTOT (fraction)	CLOUD (fraction)
CLDRAS (fraction)		
TURBU (m s^{-1} day^{-1})	TURBU (m s^{-1} day^{-1})	DUDTTRB (m s^{-2})
TURBV (m s^{-1} day^{-1})	TURBV (m s^{-1} day^{-1})	DVDTTRB (m s^{-2})

GEOS-3 name product: various on pressure	GEOS-4 name product: various on pressure & eta	GEOS-5 name product: various on lcv coordinates
GWDU (m s^{-1} day^{-1})	GWDU (m s^{-1} day^{-1})	DUDTGWD (m s^{-2})
GWDV (m s^{-1} day^{-1})	GWDV (m s^{-1} day^{-1})	DVDTGWD (m s^{-2})
		DUDTMST (m s^{-2})
		DVDTMST (m s^{-2})
		DUDTDYN (m s^{-2})
		DVDTDYN (m s^{-2})
RFU (m s^{-1} day^{-1})		
RFV (m s^{-1} day^{-1})		
UIAU (m s^{-1} day^{-1})		
VIAU (m s^{-1} day^{-1})		
DUDT (m s^{-1} day^{-1})		
DVDT (m s^{-1} day^{-1})		
TURBQ (g kg^{-1} day^{-1})	TURBQ (g kg^{-1} day^{-1})	DQVDTTRB (kg kg^{-1} s^{-1})
MOISTQ (g kg^{-1} day^{-1})	MOISTQ (g kg^{-1} day^{-1})	DQVDTMST (kg kg^{-1} s^{-1})
		DQLDTMST (kg kg^{-1} s^{-1})
		DQIDTMST (kg kg^{-1} s^{-1})
		DQVDTDYN (kg kg^{-1} s^{-1})
DQLS (g kg^{-1} day^{-1})		
QIAU (g kg^{-1} day^{-1})		
QFILL (g kg^{-1} day^{-1})		
DQDT (g kg^{-1} day^{-1})		
TURBT (K day^{-1})	TURBT (K day^{-1})	DTDTTRB (K s^{-1})
MOISTT (K day^{-1})	MOISTT (K day^{-1})	DTDTMST (K s^{-1})
DTLS (K day^{-1})		
RADLW (K day^{-1})	RADLW (K day^{-1})	DTDTLWR (K s^{-1})
RADSW (K day^{-1})	RADSW (K day^{-1})	DTDTSWR (K s^{-1})
LWCLR (K day^{-1})		DTDTLWRCLR (K s^{-1})
SWCLR (K day^{-1})		DTDTSWRCLR (K s^{-1})
RFT (K day^{-1})		DTDTFRI (K s^{-1})
GWDT (K day^{-1})	GWDT (K day^{-1})	DTDTGWD (K s^{-1})
TIAU (K day^{-1})		
DTDT (K day^{-1})	DIABDT (K day^{-1})	DTDTTOT (K s^{-1})
		DTDTDYN (K s^{-1})
KH (m^2 s^{-1})	KH (m^2 s^{-1})	KH (m^2 s^{-1})
KM (m^2 s^{-1})	KM (m^2 s^{-1})	KM (m^2 s^{-1})
CLDMAS (kg m^{-2} s^{-1})	CLDMAS (kg m^{-2} s^{-1})	CMFMC (kg m^{-2} s^{-1})
DTRAIN (kg m^{-2} s^{-1})	DTRAIN (kg m^{-2} s^{-1})	DTRAIN (kg m^{-2} s^{-1})
		DQRCON (kg m^{-2} s^{-1})
		DQRLSC (kg m^{-2} s^{-1})
		PL (Pa)
	HGHT (m)	HGHT (m)
	HGHTE (m)	HGHTE (m)
	UWND (m s^{-1})	U (m s^{-1})
	VWND (m s^{-1})	V (m s^{-1})
	TMPU (K)	T (K)
	OMEGA (Pa s^{-1})	OMEGA (Pa s^{-1})
	PV (m^2 kg^{-1} s^{-1})	PV (K m^2 kg^{-1} s^{-1})
	RH (percent)	RH (percent)
		QL (kg kg^{-1})
		QI (kg kg^{-1})
	SPHU (kg kg^{-1})	QV (kg kg^{-1})
	HKBETA (fraction)	
	HKETA (kg m^{-2} s^{-1})	

GEOS-3 name product: various on pressure	GEOS-4 name product: various on pressure & eta	GEOS-5 name product: various on lcv coordinates
	ZMDQR (kg kg^{-1} s^{-1})	
	ZMDU (Pa s^{-1})	
	ZMED (Pa s^{-1})	
	ZMEU (Pa s^{-1})	
	ZMMD (Pa s^{-1})	
	ZMMU (Pa s^{-1})	
		MFXC (kg m-2 s-1)
		MFYC (kg m-2 s-1)
		MFZ (kg m-2 s-1)

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